NUCLEATION IN SYNOPTICALLY FORCED CIRRUS

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Cold Cirrus

T<-40°C

Following Meyers et al. (1992)

Homogeneous Nucleation

- Homogeneous freezing of concentrated aqueous solution droplets at water subsaturated conditions.

Heterogeneous Nucleation

- Activation of IN in concentrated aqueous solution droplets at water subsaturated conditions.
- Deposition nucleation

?

$$\boxed{N_{nuc} = N_0 \exp[\beta(S_i - S_i^*)]}$$

N_o= 1 liter^{-1}

S_i: supersaturation ratio wrt. ice

$\beta = \beta$ (T, w, IN species)

$S_i^* = S_i^*$ (T, w, IN species)

$$N_{nuc} = N_0 \exp[\beta(S_i - S_i^*)]$$

Meyers et al (1992): Deposition-Condensation Freezing

-7 >T > -20°C, 0.25 > S_i> 0.02

β ~ 12.96, S_i^*~ 0.0493 (hereafter, M92)

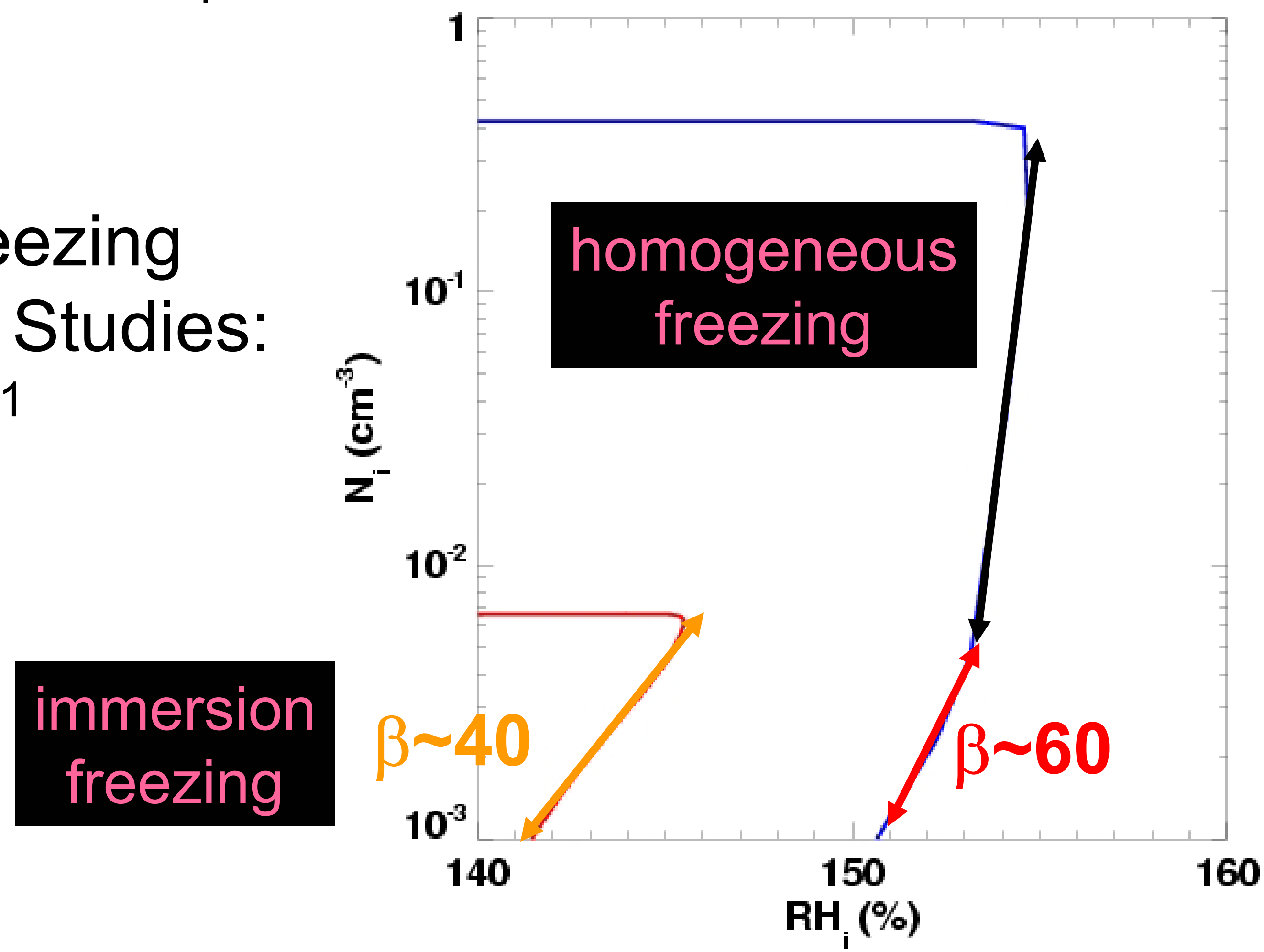
Immersion freezing Parcel Model Studies:

w = 0.04 m s^{-1}

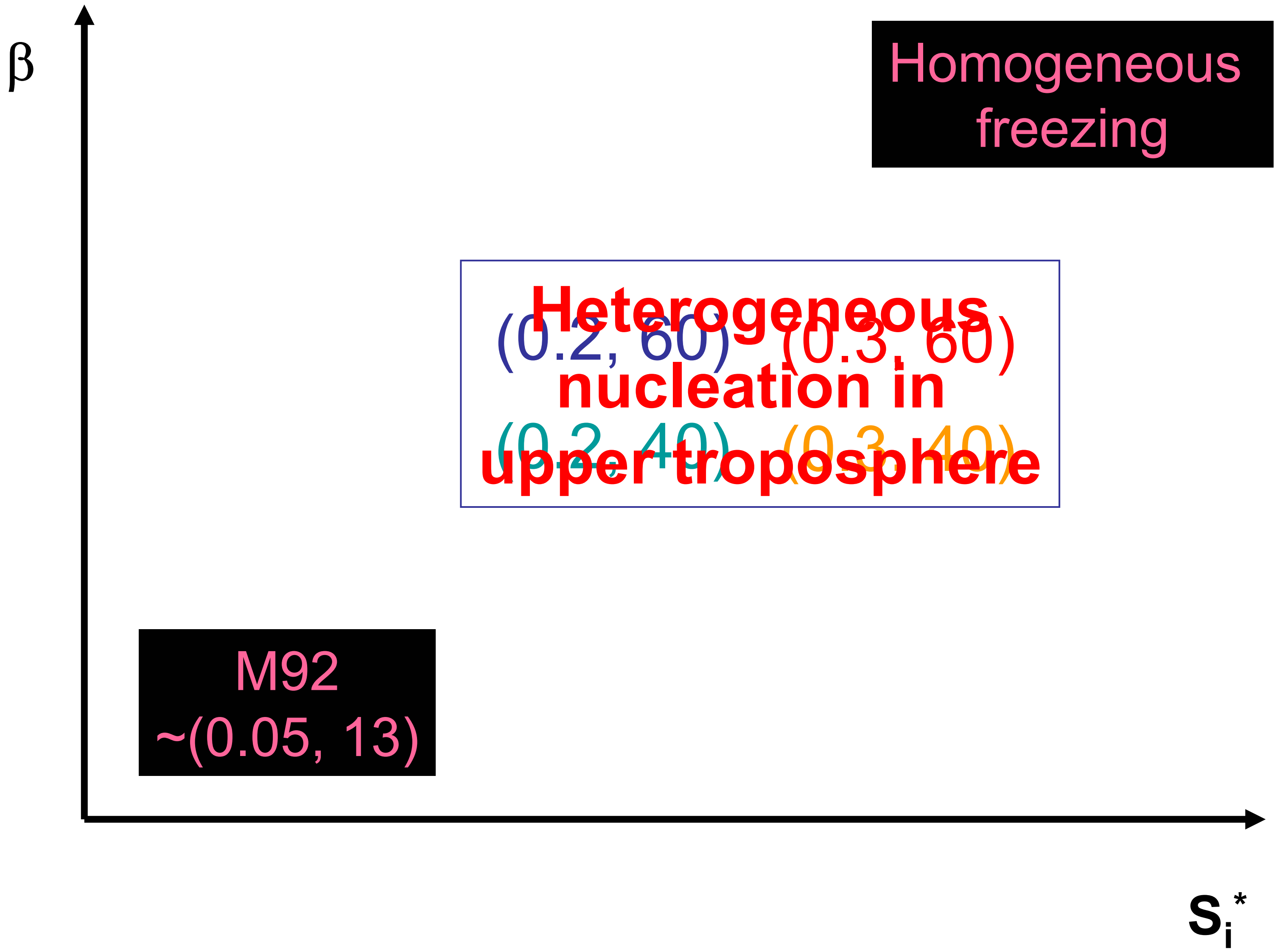
T = -60°C

T = -40°C

(DeMott)

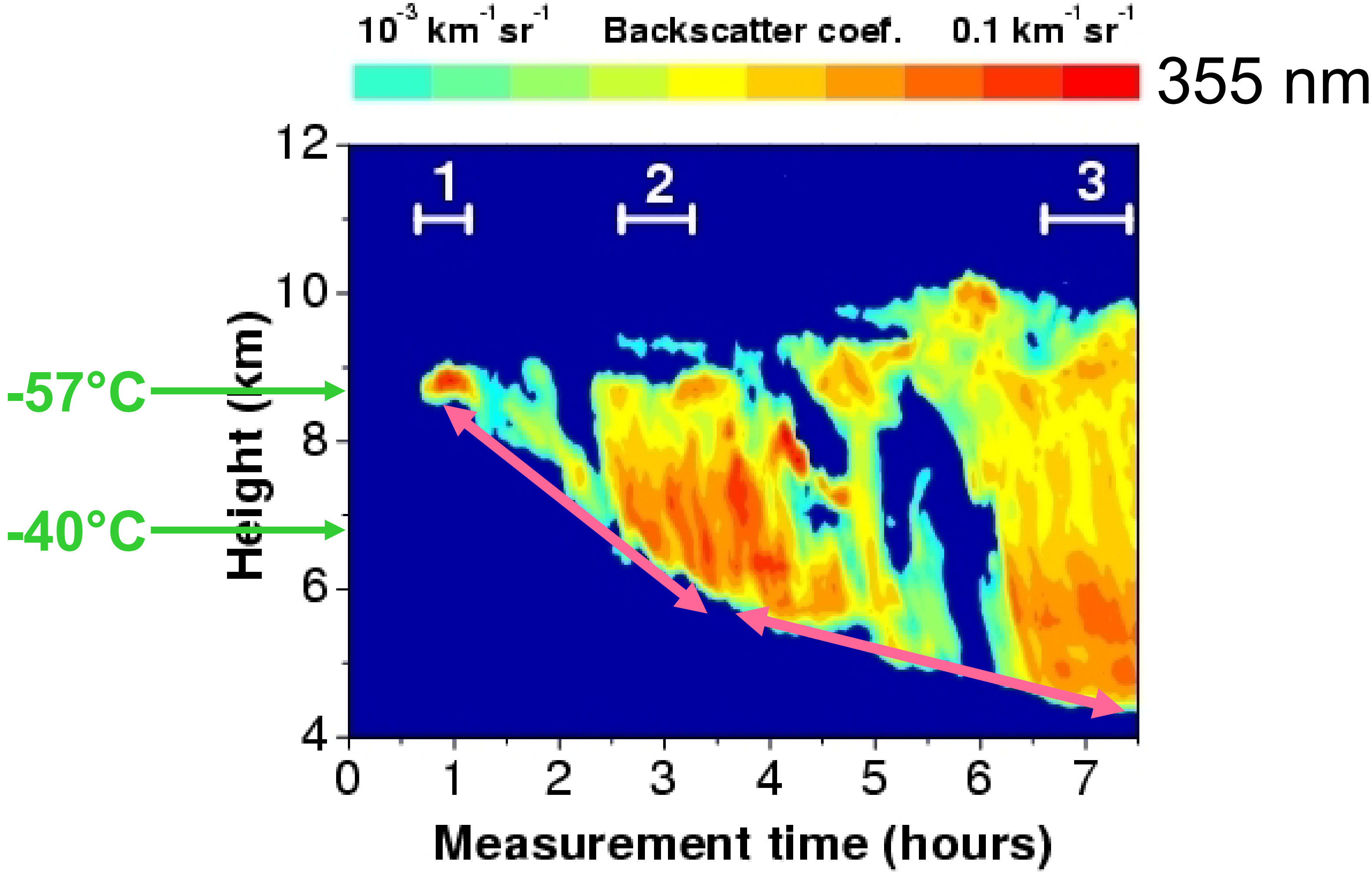


(S_i^*, β)



β
Homogeneous freezing
Heterogeneous nucleation in upper troposphere
(0.2, 60)
(0.3, 60)
(0.2, 40)
(0.3, 40)
M92
~(0.05, 13)
S_i^*

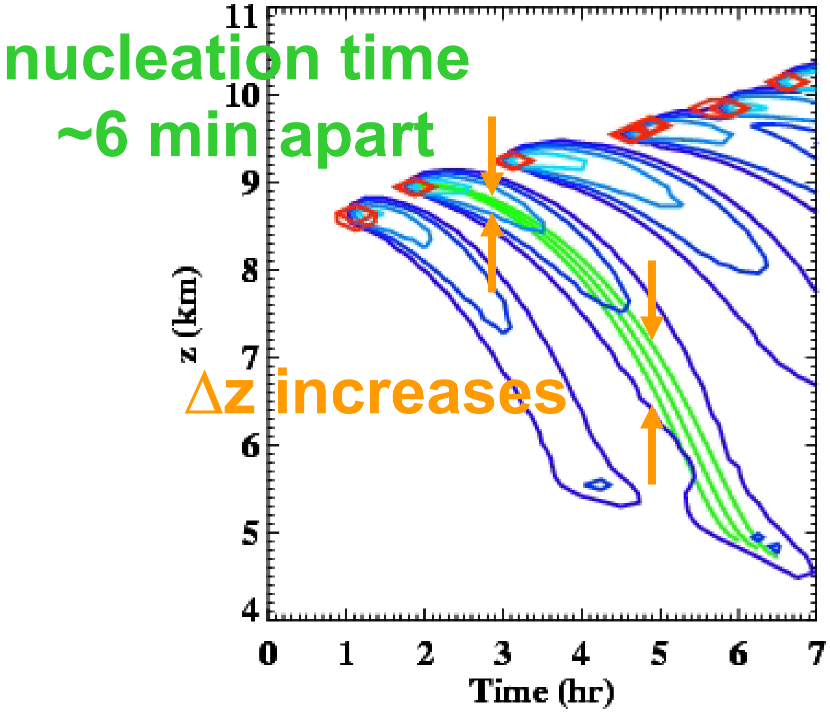
Cirrus cloud measured over northern Sweden.



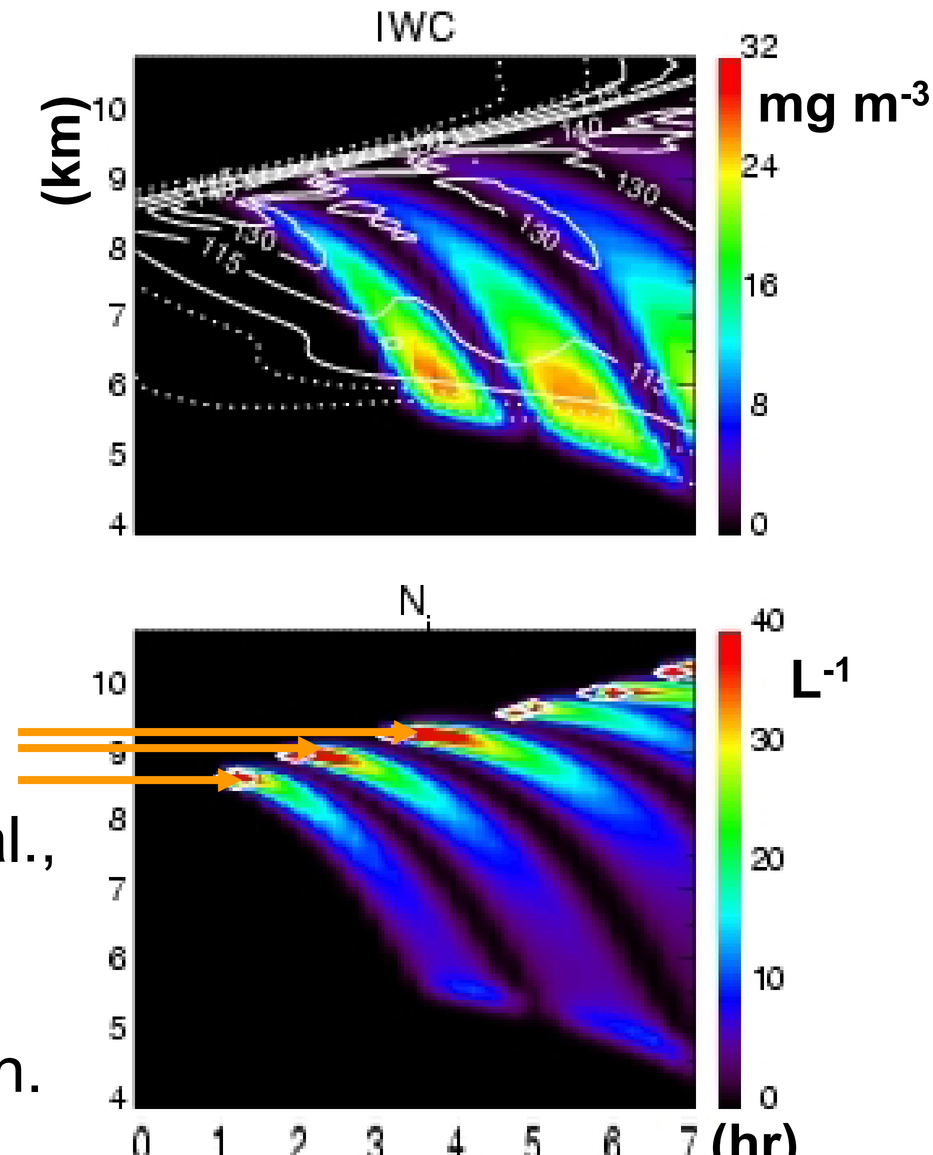
Reichardt et al. (2002), GRL, **29**, 10.1029/2002GL014836.

1D Cirrus Simulation with Explicit Microphysics

Ice particle trajectories



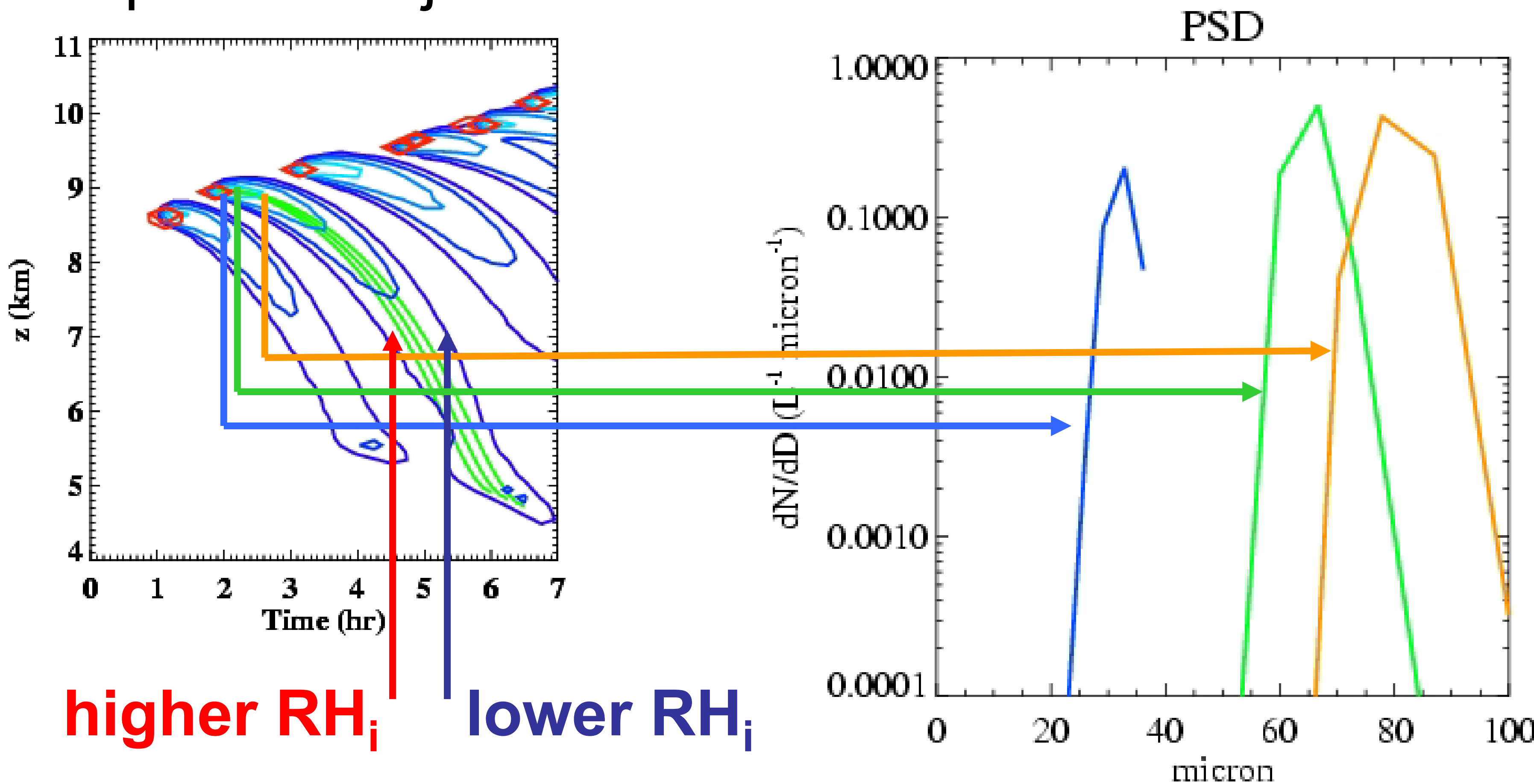
Homogeneous freezing



Nucleation pulse (Sassen and Dodd, 1989; Khvorostyanov et al., 2001) at the very top of each cloud episode.

Nucleation lasts for about 15 min.

Ice particle trajectories

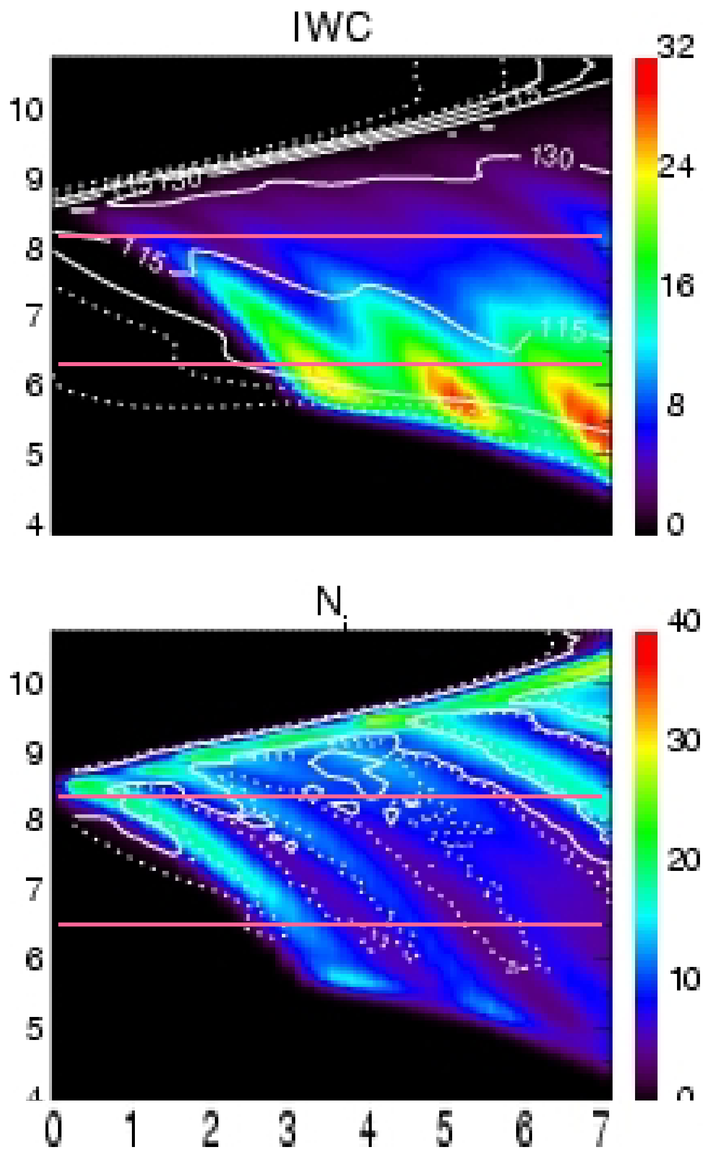


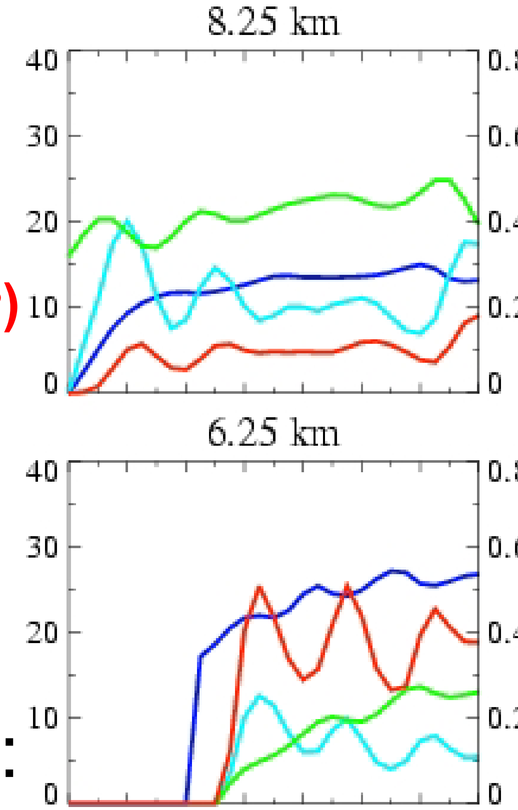
LONG NUCLEATION DURATION

N_i generated at the cloud top
does not provide sufficient information of
N_i in the mass bearing regime

1D Cirrus Simulation with Explicit Microphysics

Heterogeneous Nucleation M92





Nucleation:

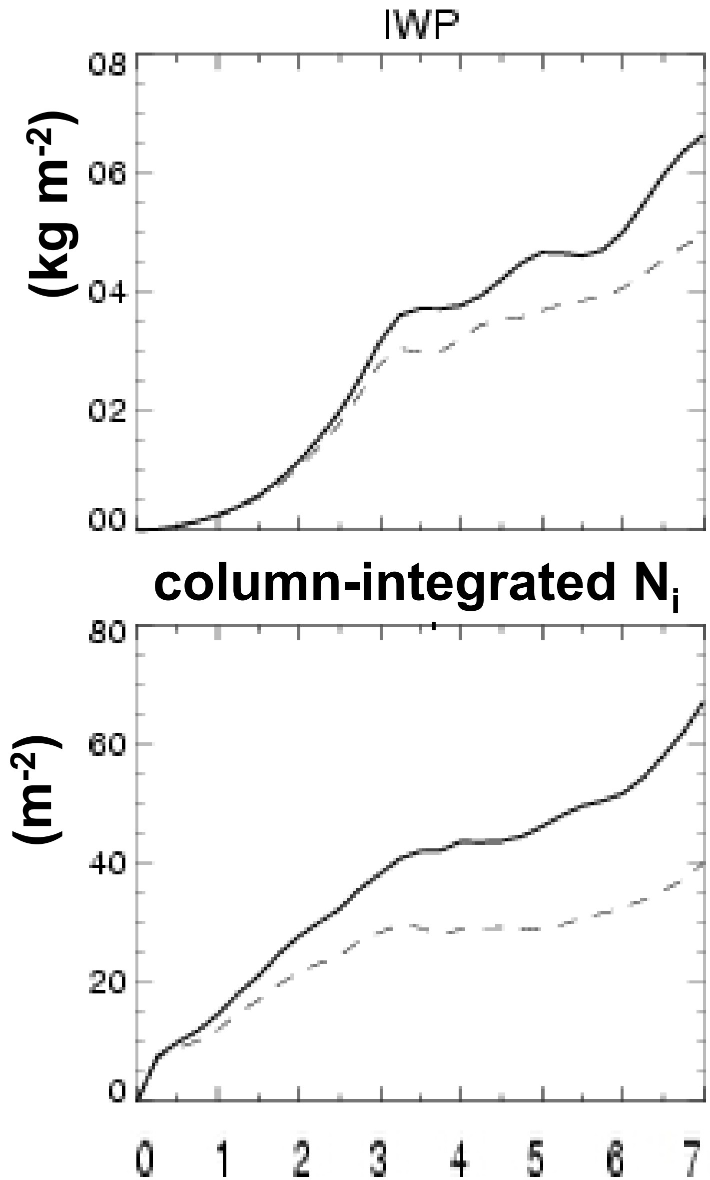
Cloud top: continuous, small variation with time

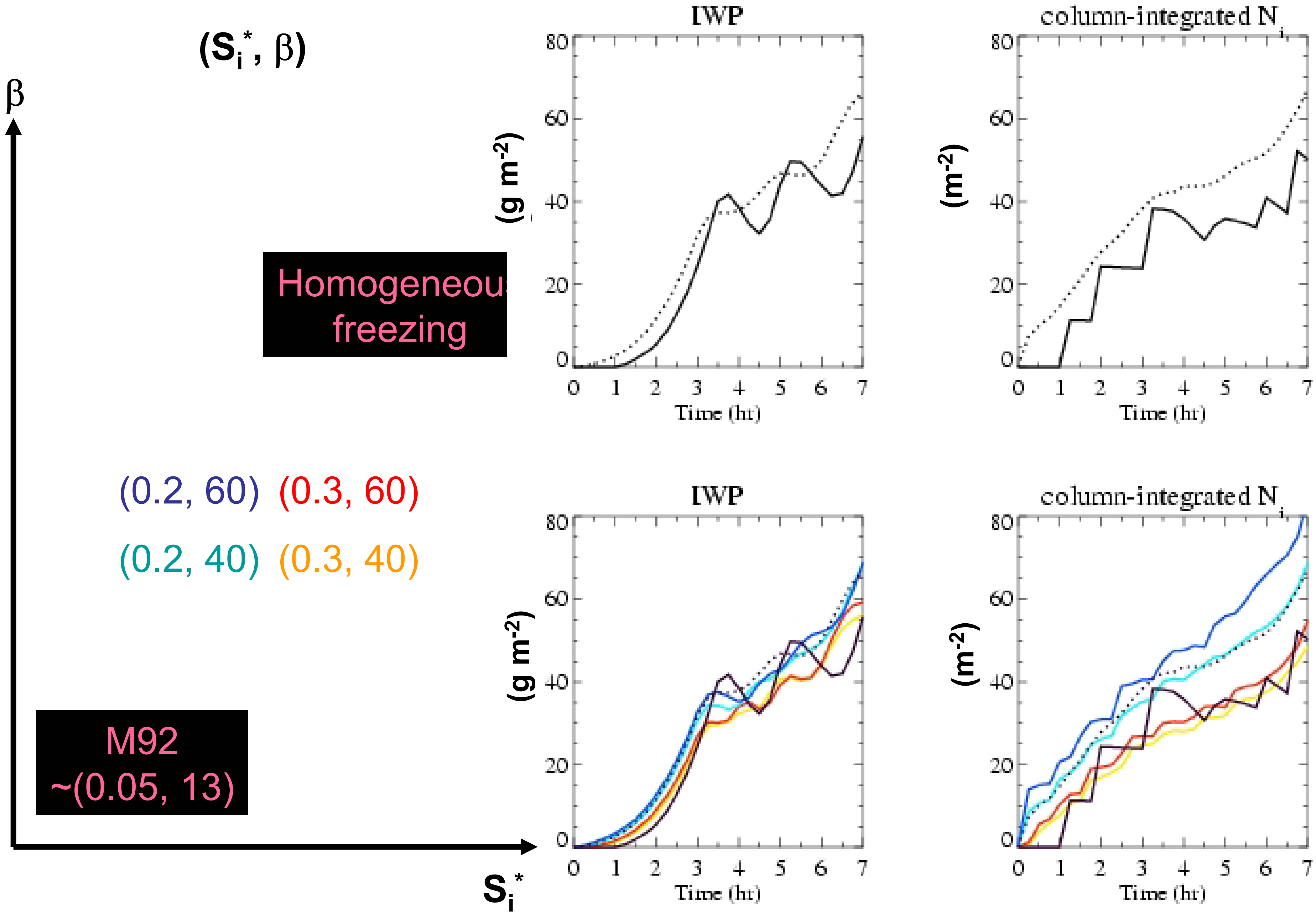
Mid-cloud: intermittent, active when RH is on the rise and IN are available

Average cloud properties are sensitive to mid-cloud nucleation

solid: control run

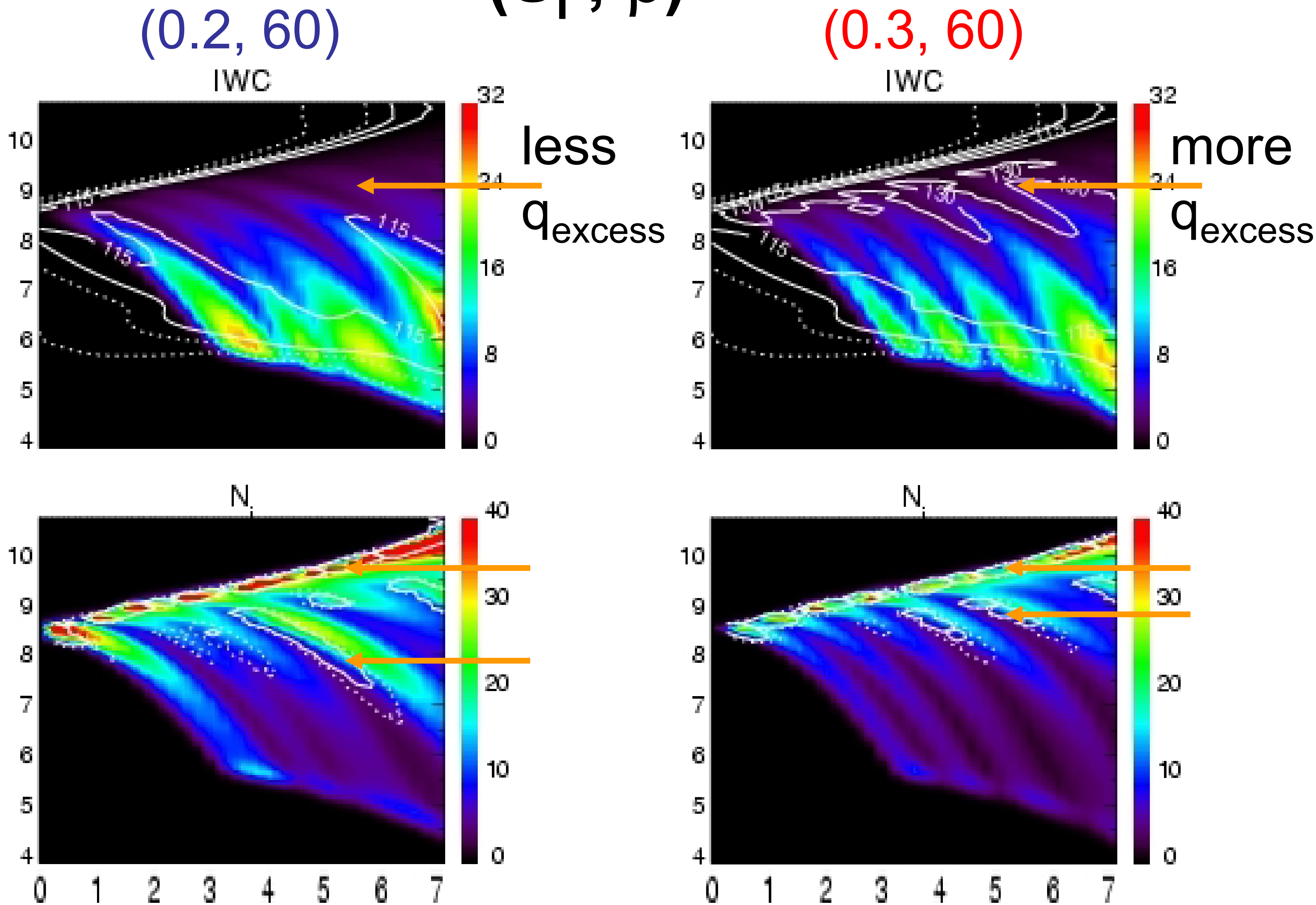
dashed: mid-cloud nucleation switched off





(S_i^*, β)
β
Homogeneous freezing
(0.2, 60) (0.3, 60)
(0.2, 40) (0.3, 40)
M92
~(0.05, 13)
S_i^*
IWP
($g\ m^{-2}$)
Time (hr)
column-integrated N_i
(m^{-2})
Time (hr)
IWP
($g\ m^{-2}$)
Time (hr)
column-integrated N_i
(m^{-2})
Time (hr)

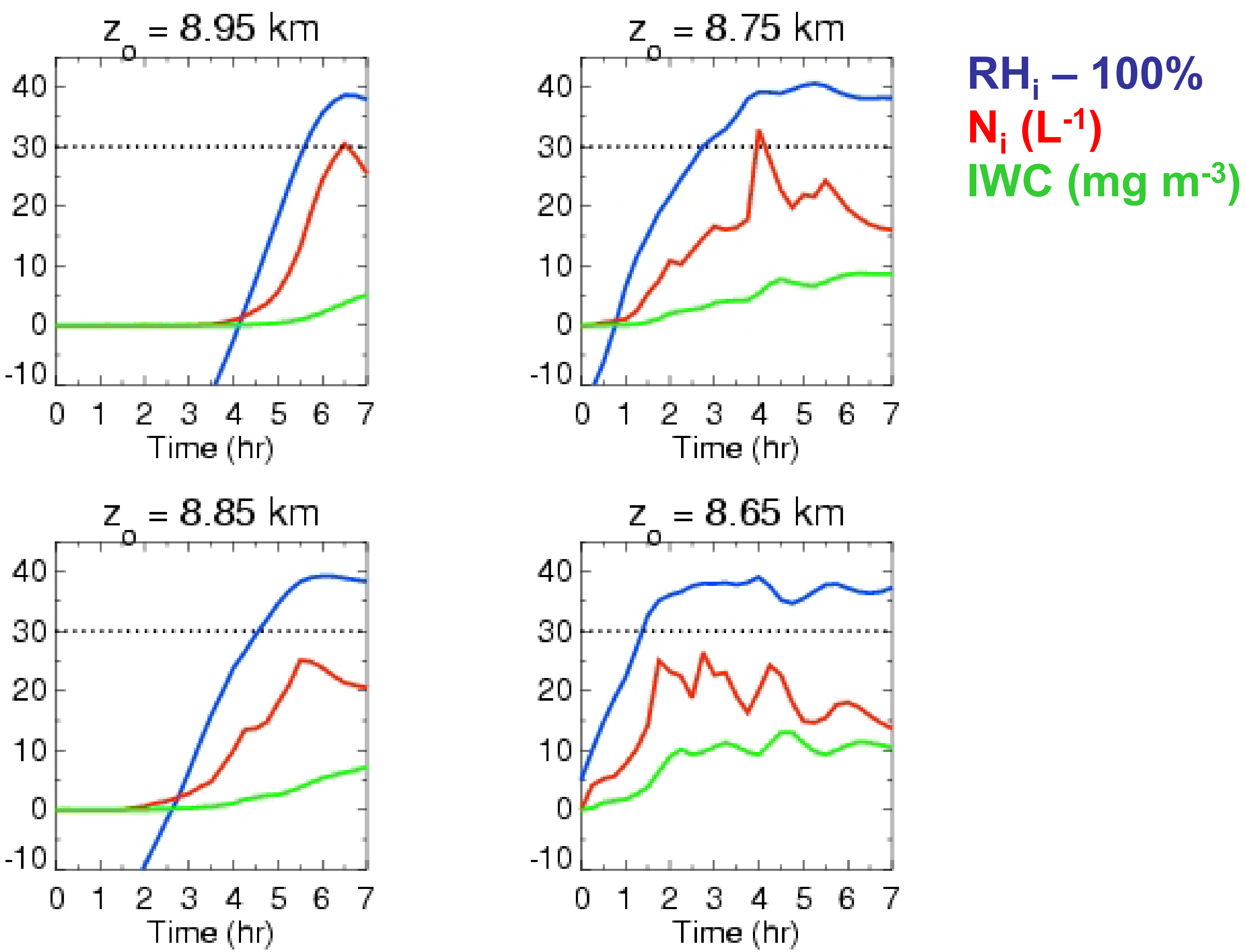
(S_i^*, β)


(0.2, 60)
(0.3, 60)
IWC
IWC
less
q_{excess}
more
q_{excess}
N_i
N_i
115
130
0
1
2
3
4
5
6
7
4
5
6
7
8
9
10
0
8
16
24
32
0
10
20
30
40

Summary

- **Synoptically forced cirrus: long duration of nucleation period.** N_i at nucleation zones does not provide sufficient information of N_i in the cloud mass bearing regions.
- Preliminary results show that **the average cloud properties do not respond to S_i^* and β monotonically**. Sensitivity tests must cover a reasonable "2-dimensional" range of these two parameters.
- For the limited range of (S_i*, β) studied here, the average cloud properties are more sensitive to S_i^*. Smaller S_i^* entails less excess water vapor, more cloud ice, larger nucleation zone, and more ice crystals.

Following ascending parcels



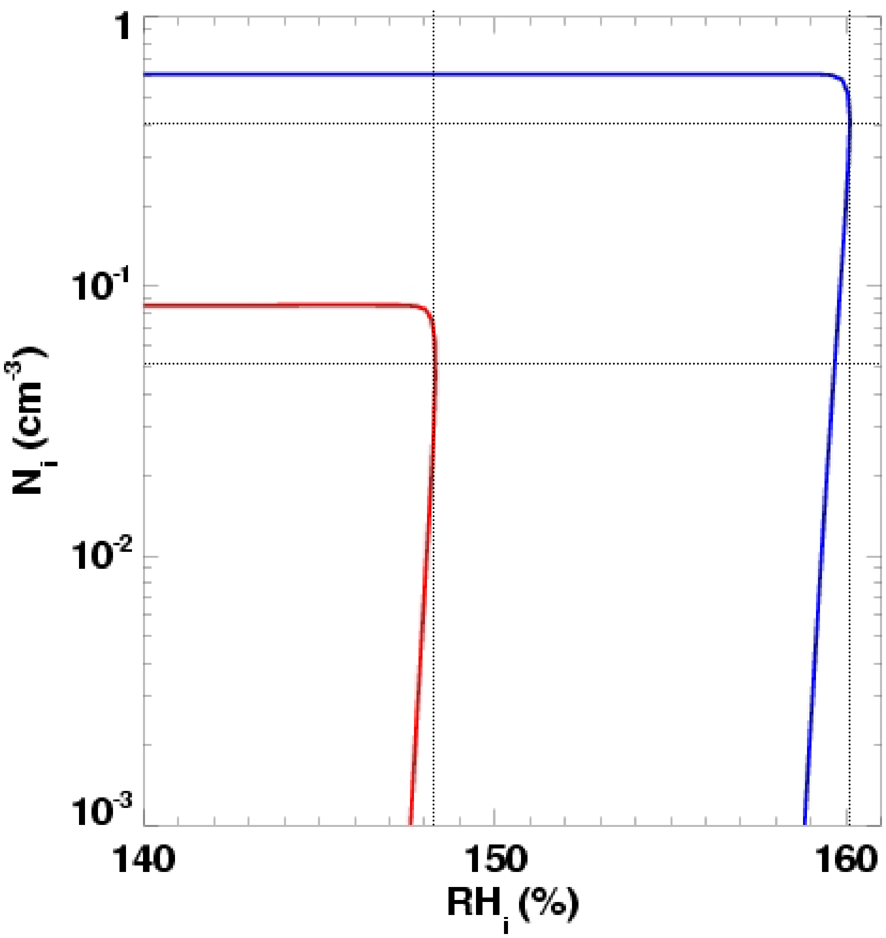
$$N_{nuc} = N_0 \exp[\beta(S_i - S_i^*)]$$

Homogeneous freezing (from Parcel Model Studies)

w = 0.04 m s^{-1}

T = -60°C

T = -40°C



Caveat: May underestimate N_{nuc}